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September 1980

U.S./CANADA WHEAT AND BARLEY CROP CALENDAR EXPLORATORY EXPERIMENT IMPLEMENTATION PLAN

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U.S./CANADA WHEAT AND BARLEY CROP CALENDAR EXPLORATORY EXPERIMENT IMPLEMENTATION PLAN

This document describes an Accuracy Assessment Experiment on the evaluation of crop calendar models to be conducted in support of the U.S./Canada Wheat and Barley Exploratory Experiment for the Foreign Commodity Production Forecasting Project.

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September 1980

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ACRONYMS

AgRISTARS	Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
CY	crop year
FCPF	Foreign Commodity Production Forecasting
FY	fiscal year
JTCT	Joint Technical Coordination Team
LACIE	Large Area Crop Inventory Experiment
LARS	Laboratory for Applications of Remote Sensing
MSE	mean square error
MYE	man-year equivalents
pixels	picture elements
PTRR	Preliminary Technical Review Report
SAS	Statistical Analysis System
SR	Supporting Research
USGP	U.S. Great Plains
USNGP	U.S. Northern Great Plains

1. INTRODUCTION

1.1 EXPERIMENT BACKGROUND

The Foreign Commodity Production Forecasting (FCPF) Implementation Plan (ref. 1), dated January 15, 1980, provides for a category 3 (test and evaluation) experiment for U.S./Canada wheat and barley to be completed in fiscal year 1980 (FY80). A wheat and barley labeling experiment plan (ref. 2) and a plan for an evaluation of a Procedure 1A technology (ref. 3) were developed to support that exploratory experiment.

This document is a detailed plan for a supplemental experiment to evaluate several crop growth stage and crop starter models. This experiment is a joint effort of the Supporting Research (SR) and FCPF Projects of the Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) Program. Ground observations of spring wheat and barley crop growth stages made during the 1979 crop year (CY79) in the U.S. Northern Great Plains (USNGP) and normal (historical) growth stage estimates will be compared with model predictions in these evaluations. These agro-meteorological models were recommended for testing by the SR Project and are candidates for use during the U.S./Canada wheat and barley pilot experiment in FY81.

During the Large Area Crop Inventory Experiment (LACIE), spring wheat crop calendars based upon historical normals were improved through the development of crop calendars adjusted by daily maximum and minimum temperatures and day lengths (ref. 4). Modifications to this basic model (ref. 5) have resulted in variations that offer potential for improved accuracy in growth stage estimation. In addition, models for barley growth and planting date determination (ref. 6) have been identified which may support development of improved crop calendars.

1.2 OBJECTIVES

The general objectives of this experiment are to provide timely information to aid in understanding crop calendars and to provide data that will support a selection between current crop calendar models.

Recommendations on whether or not to use a specific combined planting date model and growth stage model (or models) in the follow-on exploratory and pilot experiments will be made after evaluating the results of this experiment. Recommendations for further research will also be developed.

1.3 APPROACH

The following crop growth models and starter models will be tested and evaluated in the experiment.

a. Spring Wheat Growth Stage Models

1. Robertson
2. Improved Robertson, version 1
3. Improved Robertson, version 2

b. Barley Growth Stage Model

Williams

c. Starter Model

Feyerherm

Comparisons of these models will be with normal (historical) growth stage estimates (including planting dates) and with CY79 periodic observations made at 51 segments in the U.S. Great Plains (USGP).

1.4 COMPONENTS' ROLES

Component elements having major roles in the experiment are Crop Calendars, Experiment Design, and Accuracy Assessment.

Component implementation planning for this supplemental exploratory experiment is described in subsequent sections followed by summaries of (a) data and system requirements, (b) resources, and (c) an integrated experiment schedule.

Component responsibilities are stated in the FCPF Implementation Plan (ref. 1). Overall conformance to the technical aspects of this experiment will be monitored by a representative of the Experiment Design Component.

1.5 PRODUCTS, REPORTS, AND DOCUMENTATION

Each of the technical components will interchange and produce products as specified in the individual component sections. Results from evaluations will be reported on a component basis to be compiled into a Preliminary Technical Review Report (PTRR). Formal documentation of experiment results and recommendations for future pilot experiments and further development will follow the preliminary report.

2. EXPERIMENT DESIGN

2.1 BACKGROUND

In the LACIE and presently in the FCPF Project, inventories of specific crops of interest are conducted over large areas using Landsat satellite data. This requires the identification of target samples by a labeling procedure for the crop of interest. The spectral signature representing the target sample for a crop of interest depends on a variety of factors such as crop development stage, soil type, moisture conditions, and haze. The most important element for purposes of identification of the crop type is the crop development stage. Current labeling procedures depend upon the knowledge of what crop development stage is expected for the crop of interest during the times that the Landsat data were required.

Beginning with LACIE, models have been used to predict crop development over extended areas. These models are referred to as agromet models because they estimate the daily rate of phenological development as a function of day length and maximum and minimum air temperature. The model used during LACIE (ref. 4) was developed by Robertson for spring wheat. The basic form is

$$DID = [a_1(DL - a_0) + a_2 (DL - a_0)^2] [b_1(TX - b_0) + b_2 (TX - b_0)^2 + c_1(TN - b_0) + c_2(TN - b_0)^2]$$

where

DID = daily increment of development

DL = day length in hours

TX = daily maximum air temperature

TN = daily minimum air temperature

a_i, b_i, and c_i are characteristic coefficients, $i = 0, 1, 2$

The characteristic coefficients are specifically defined for each growth stage of the crop of interest. Two attempts have been made to formulate

coefficients that would have more realistic physiological responses for spring wheat. The first was by Cate, et al. (ref. 5); the second is from additional SR Project research. These agromet models for spring wheat are referred to in this document as the Robertson model; the improved Robertson model, version 1; and the improved Robertson model, version 2. Coefficients for a spring barley model have been developed by Williams. This basic form of crop development models requires an initiation date. Starter models have been formulated to predict this initiation date. Starter models may be initiated simply by using a historical average planting date or by using planting dates modified, for instance, as a function of mean daily air temperature (Feyerherm, ref. 7).

2.2 OBJECTIVES

To satisfy the general objectives of this experiment, three issues will be studied:

1. Which combination of planting date model and growth stage model is expected to most accurately predict the growth stage as a function of time for spring wheat and for barley?
2. Does the Williams barley model more accurately predict the barley growth stages than the spring wheat model?
3. Do the models selected perform well enough to be used in the labeling procedures?

2.3 APPROACH

This crop calendar evaluation naturally lends itself to division into four separate parts. The first two support Issue 1; the third and fourth support Issues 2 and 3, respectively. The four parts are:

a. Planting date model evaluation

b. Spring wheat growth stage model evaluation

c. Williams barley model accuracy evaluation

d. Biowindow prediction accuracy

These four parts of the evaluation will contribute substantially toward the selection of which spring wheat model to use, whether or not the barley model is useful, and whether or not the Feyerherm starter model is of value.

The data set for the planting date model evaluation consists of ground truth observation of planting date for individual spring wheat and barley fields, for historical normal planting dates for the area of the segment, and for Feyerherm planting date model predictions for the segment.

The four crop growth stage models were started using (a) the observed field stages, (b) the median observed field stage, (c) the normal segment planting date, and (d) the Feyerherm segment planting date prediction. The growth stage model predictions were then made for each date of the periodic observation.

The 1979 spring wheat and barley sites in the USNGP (standard data set 1R, see reference 8) contain about 51 segments with 9- or 18-day periodic observations of ground-truth growth stage development. Each segment has from 15 to 30 spring wheat and barley fields observed. In total, there are 6604 observations for use in this study.

2.4 PRODUCTS, REPORTS, AND DOCUMENTATION

The technical aspects of this experiment will be monitored by a representative of the Experiment Design Component. Recommendations for future exploratory and pilot experiments will be provided for the PTRR and the final project experiment report.

3. ACCURACY ASSESSMENT

3.1 OBJECTIVES

The objectives of the Accuracy Assessment Component are to evaluate the accuracy of the planting date models and the crop calendar models and to determine the combination of planting date model and growth stage model which will most accurately predict the growth stage as a function of time for spring wheat and for barley. In addition, the barley crop calendar will be evaluated to determine if it predicts the barley growth stages more accurately than the spring wheat model. The final crop calendars selected will be evaluated on their ability to produce results accurate enough to be used in the spring wheat and barley labeling procedure.

3.2 APPROACH

The crop calendars will be evaluated using periodic observations from CY79 for 51 segments in the spring wheat areas of the USGP. This data set consists of growth stage observations taken every 9 or 18 days for a number of spring wheat and barley fields in each segment and represents the most complete data set available.

The planting date models and growth stage models will be evaluated independently to determine which planting date model is best and which growth stage model is best. These evaluations will be done on a regional basis to see if the models' performance varies from region to region. The final evaluation of the selected crop calendars will be done in terms of the crop calendars' ability to determine the acquisition windows defined by the reformatted spring wheat and barley labeling procedure.

The evaluations will be performed on the Laboratory for Applications of Remote Sensing (LARS) computer system using the Statistical Analysis System (SAS) routines. The data for the evaluation will be provided by the Crop Calendar Component. This component will provide both the model predictions and periodic observations for each observation. The data will be provided in a disk file on the LARS computer system.

The following ranges of Robertson crop growth stages will be used to evaluate the performance of the various models for spring wheat and for barley:

a. Crop stages 2.0 to 2.9

b. Crop stages 3.0 to 3.9

c. Crop stages 4.0 to 4.9

d. Crop stages 5.0 to 5.9

e. Crop stage 6.0

In addition, the models will be evaluated for the entire growing season from stages 2.0 to 6.0 in order to estimate the overall performance of the models.

For stages 2.0 to 5.9, the Friedman Test (ref. 9) will be used to determine if one of the models produces significantly different results from the other models. The variable for this test will be the absolute value of the error produced by a model for a segment. Each segment will be a block. Each model will be a treatment. By ranking the model predictions for each segment, the Friedman Test can be used to determine if one model produces significantly better results than the other models.

3.2.1 PLANTING DATE MODEL EVALUATION

Two planting date models will be evaluated. The first model provides the normal planting date for the segment based on historical data. The second model is the Feyerherm model; this model uses weather data to determine the planting date.

The models will be evaluated on their ability to accurately predict the observed median planting date for the segment. The accuracy will be characterized by the error in days between the model prediction and the observed date. Some measures of the accuracy which will be used to determine the best model are the mean error in days, the distribution of the error, and the mean square error (MSE). In addition, the percentage of the segments for which one model produces a better estimate than the other will be used to determine which model is best.

3.2.2 GROWTH STAGE MODEL EVALUATION FOR SPRING WHEAT

As stated in section 2.1, three spring wheat growth stage models which will be evaluated: the original Robertson model and two improved models. Each of the models uses weather data to determine the rate at which the growth stages change.

The models will be evaluated using the observed median planting date as input to the model. (In addition, the individual field planting dates will be used to start the models to determine the ultimate performance of the models.) The evaluation will be made on the basis of the models' ability to accurately predict the observed median growth stages. Evaluations will be completed for each of the stages in the observations. Some measures of the accuracy which will be used to determine the best model are the mean error in crop growth stage, the distribution of the error, and the percentage of the segments in which one model produced better estimates than the other.

3.2.3 EFFECTIVENESS OF THE WILLIAMS BARLEY MODEL

In order to determine if the barley growth stage model is more accurate than the spring wheat model in predicting the barley growth stages, each model will be run using the observed median planting date for barley as input. Using the criteria for growth stage model evaluation, the best barley growth stage predictor will be determined. If the spring wheat model is better than the barley model in predicting the barley growth stage, then only the spring wheat model is needed to predict the growth stage for both spring wheat and barley.

3.2.4 EVALUATION OF THE ACCURACY OF PREDICTING ACQUISITION WINDOW LOCATIONS

The final choices for crop calendar models will be evaluated in terms of their ability to accurately predict the acquisition window locations as defined by the spring wheat/barley reformatted labeling procedure. The best spring wheat planting date and growth stage models will be used to predict the location of acquisition windows 1, 2, and 4. The best barley planting date and growth stage models will be used to predict the location of acquisition window 3. The predicted window location will be compared with the window location

derived from the observations. Two measures of accuracy which will be used are (a) the percent overlap between the predicted and observed window locations and (b) the displacement in days in the two-window locations.

3.3 REPORTS AND DOCUMENTATION

A "quick-look" report will be prepared containing the preliminary results and recommendations derived from this evaluation and a final accuracy assessment report will follow. Support will be provided for the PTRR and the final project report.

4. CROP CALENDARS

4.1 OBJECTIVES

The SR Project has two primary objectives in the evaluation of agromet crop stage estimation models. The first is a statistical summary of model performance sufficient to allow SR Project scientists to select the models for use in FCPF exploratory and pilot experiments. The second is an identification of any systematic model bias either by stage or geographical location.

The Accuracy Assessment evaluation will provide the basis for model selection and identification of potential model bias.

4.2 APPROACH

The SR Project will provide to the Accuracy Assessment Component the following data products to be used in this evaluation:

a. Normal planting dates for spring wheat and barley for each test segment

b. Results of model runs along with coincident CY79 ground-truth observations of growth stage by field for spring wheat and barley

   Four models will be run:

   1. Robertson model
   2. Improved Robertson model, version 1
   3. Improved Robertson model, version 2
   4. Williams model

   These models will be started in the following ways:

   1. Feyerherm planting date estimate
   2. Segment median planting date based on ground truth for wheat and barley
   3. Actual planting date for each wheat and barley field
   4. Normal planting date for each segment

c. The actual planting date for each field along with the Feyerherm planting date estimate

All products will be delivered to the Accuracy Assessment Component in the form of data files on the LARS computer system. The format of the data files will be coordinated with Accuracy Assessment.

All models in this study will be run daily meteorological data taken at the nearest possible climatological station to the test segments.

In addition to data products, the SR Project will provide technical advice as needed.

4.3 PRODUCTS, REPORTS, AND DOCUMENTATION

The SR project will provide to the Accuracy Assessment Component the required (a) normal planting dates, (b) results of model runs with coincident ground-truth observations, and (c) Feyerherm-model-determined planting dates and actual planting dates in the form of data files as outlined in section 4.2.

Support for the preparation of the PTRR will be provided. Recommendations based upon the Accuracy Assessment evaluation regarding model selection and further crop calendar research will be submitted for inclusion in the final U.S./Canada Wheat and Barley Exploratory Experiment report.

5. DATA AND SYSTEMS REQUIREMENTS SUMMARY

The data and systems requirements necessary to support the components of this experiment are summarized in this section.

5.1 EXPERIMENT DESIGN COMPONENT

In order to make recommendations for future exploratory and pilot experiments, the Experiment Design Component requires the final accuracy assessment analysis results.

5.2 ACCURACY ASSESSMENT COMPONENT

The Accuracy Assessment Component will receive the model of predicted and observed data from the Crop Calendar Component in the form of a disk file on the LARS computer system. The SAS routines on the LARS computer system will be used to perform the evaluations.

5.3 CROP CALENDAR COMPONENT

Meteorological data for model runs will be extracted from literature available locally. Ground observations are currently available within the Crop Calendar Component. Model runs will be made on the LARS 3031 computer.

6. EXPERIMENT SCHEDULE AND RESOURCE SUMMARY

Pursuant to the FCPF Implementation Plan (ref. 1), an exploratory experiment for wheat and barley in the United States and Canada has been scheduled for FY80. Supplemental to this experiment, a small grain wheat and barley exploratory proportion estimation experiment and a crop calendar experiment have been planned. The testing and evaluation of candidate procedures and crop calendars for follow-on exploratory and pilot experiments will be reported in a PTRR followed by a formal document early in FY81. The PTRR presentation is currently scheduled (consistent with data and critical resource availability) to allow the earliest possible incorporation of findings into FY81 experiment planning.

6.1 EXPERIMENT SCHEDULES

In order for an experiment to arrive at a successful conclusion, an integrated schedule must be developed portraying each component's relationship to the other. The experiment schedule shows this relationship in summary form (fig. 6-1).

6.2 RESOURCE SUMMARY

Resources necessary to conduct this exploratory experiment will be drawn from those provided for the project as defined by task sheet in the FCPF and SR Projects Implementation Plans. Resource scoping across organizational elements is generally consistent with individual task sheet estimates. Both civil service and contractor personnel are involved to varying degrees in all facets of the experiment. The following sections present the projected requirements for civil service and contractor personnel.

6.2.1 CIVIL SERVICE RESOURCE SUMMARY

Civil service personnel are engaged in numerous tasks relating to Project Management and Support that are involved in directing and monitoring the Experiment Design, Crop Calendar, and Accuracy Assessment contractor effort. Total civil service manpower involved in this experiment is 2 man-weeks.

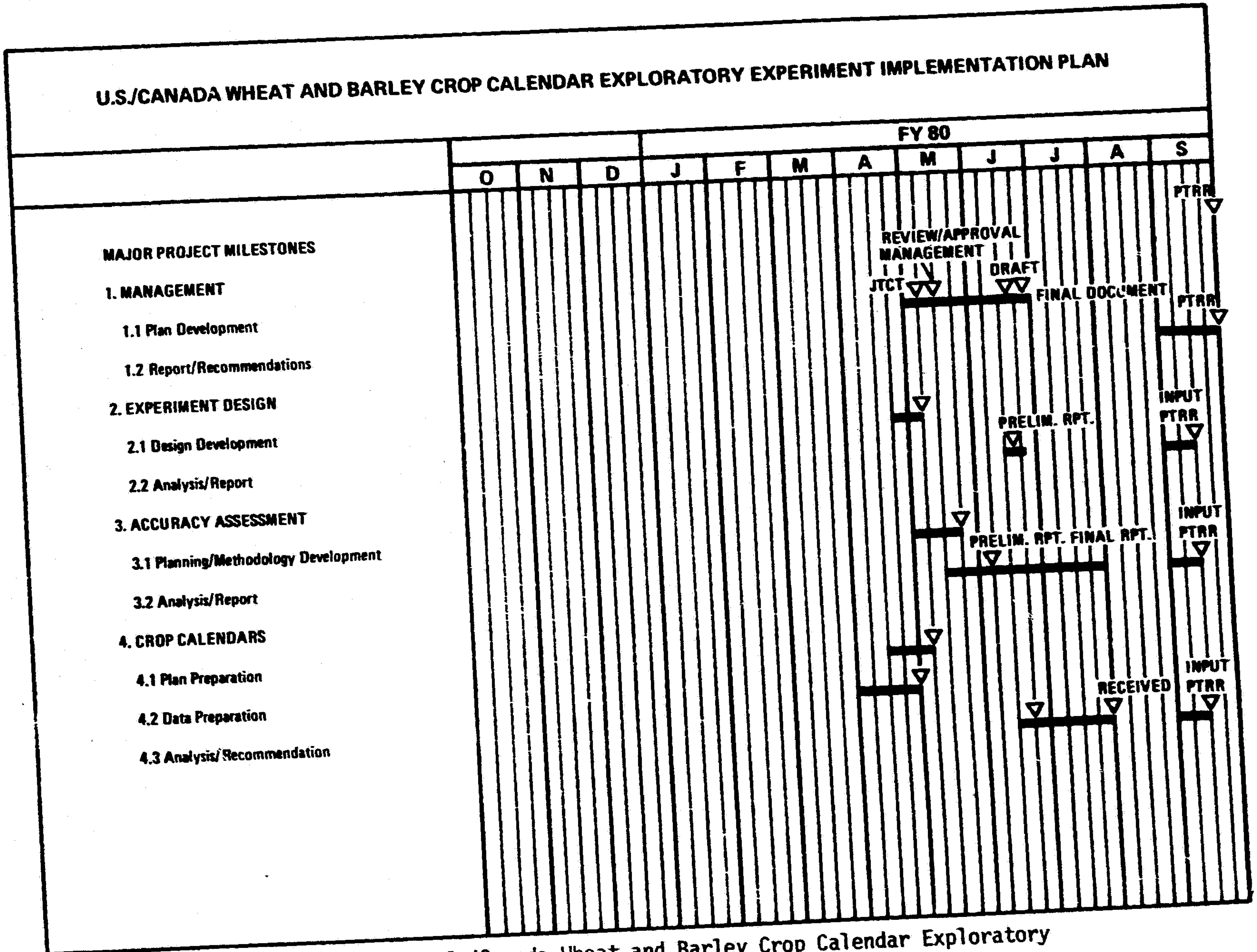

Figure 6-1.- The U.S./Canada Wheat and Barley Crop Calendar Exploratory Experiment Implementation Plan schedule.

6.2.2 CONTRACTOR RESOURCE SUMMARY

Contractor personnel participate in the implementation of this experiment through all of the components. The level of manpower involvement on a per component basis is shown in table 6-1.

TABLE 6-1.- CONTRACTOR MAN-YEAR EQUIVALENTS (MYE) PER COMPONENT

Section	Component	Support Contractor MYE
1.	Experiment Plan Development	0.1
2.	Experiment Design	0.1
3.	Accuracy Assessment	0.25
4.	Crop Calendars	0.1
5.	Data and Systems Summary	—
6.	Experiment and Resource Summary	—

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